

## Circumnuclear Star-Forming Regions in Early Type Spiral Galaxies

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### 1. Summary and Conclusions

We discuss measurements, from high dispersion spectra, of gas and stellar velocity dispersions in 17 circumnuclear star-forming regions (CNSFRs) and the nuclei of three barred spiral galaxies: NGC 2903 (Hägele et al. 2009), NGC 3310 (Hägele et al. 2010) and NGC 3351 (Hägele et al. 2007). The stellar dispersions have been obtained from the Ca II triplet (CaT) lines at  $\lambda\lambda$  8494, 8542, 8662 Å that originate in the atmospheres of red giant and supergiant stars belonging to the underlying stellar population of the clusters, while the gas velocity dispersions have been measured by Gaussian fits to the H $\beta$   $\lambda$  4861 Å and [O III]  $\lambda$  5007 Å lines.

The CNSFRs, with sizes of  $\sim 100$  to  $150$  pc in diameter, are seen to be composed of several individual star clusters with sizes between  $1.5$  and  $6.2$  pc on *Hubble Space Telescope* (HST) images. Stellar velocity dispersions are between  $31$  and  $73$  km s<sup>-1</sup>. For NGC 2903 and NGC 3351 these values are about  $25$  km s<sup>-1</sup> larger than those derived for the gas from the H $\beta$  emission line using a single Gaussian fit. For NGC 3310 these values and those derived for the gas from the H $\beta$  emission line using a single Gaussian fit are in relatively good agreement, with the former being slightly larger. However, the best Gaussian fits involve two different components for the gas: a “broad component” with a velocity dispersion similar to that measured for the stars for NGC 2903 and NGC 3351 (and larger by about  $20$  km s<sup>-1</sup> for NGC 3310), and a “narrow component” with velocity dispersions lower than the stellar one by about  $30$  km s<sup>-1</sup>. This “narrow component” seems to have a relatively constant value for all the CNSFRs studied in these three galaxies, with estimated values close to  $25$  km s<sup>-1</sup> for the two gas emission lines.

Upper limits to the dynamical masses estimated from the stellar velocity dispersion using the virial theorem for the CNSFRs of NGC 2903 are in the range between  $6.4 \times 10^7$  and  $1.9 \times 10^8$  M<sub>⊙</sub> and is  $1.1 \times 10^7$  M<sub>⊙</sub> for its nuclear region inside the inner  $3.8$  pc. In the case of NGC 3310 the masses are in the range between  $2.1 \times 10^7$  and  $1.4 \times 10^8$  M<sub>⊙</sub> for the CNSFRs, and is  $5.3 \times 10^7$  M<sub>⊙</sub> for the nuclear region inside the inner  $14.2$  pc. For NGC 3351 the dynamical masses are in the range between  $4.9 \times 10^6$

and  $4.5 \times 10^7 M_{\odot}$  for the CNSFRs and is  $3.5 \times 10^7 M_{\odot}$  for the nuclear region inside the inner 11.3 pc. Then, globally, the dynamical masses of the CNSFRs are in the range between  $4.9 \times 10^6$  and  $1.9 \times 10^8 M_{\odot}$ . Masses derived from the  $H\beta$  velocity dispersion under the assumption of a single component for the gas would have been underestimated by factors between approximately 2 to 4.

Derived masses for the individual clusters are between  $1.4 \times 10^6$  and  $1.1 \times 10^7 M_{\odot}$ , between  $1.8$  and  $7.1 \times 10^6 M_{\odot}$ , and between  $1.8$  and  $8.7 \times 10^6 M_{\odot}$  for NGC 2903, NGC 3310, and NGC 3351, respectively. Then, globally, the masses of these individual clusters vary between  $1.4 \times 10^6$  and  $1.1 \times 10^7 M_{\odot}$ . It must be noted that we have measured the size of each knot (typically between 3 and 5 pc), but the stellar velocity dispersion corresponds to the integrated CNSFR, a wider area containing several knots. The use of these wider size scale velocity dispersion measurements to estimate the mass of each knot leads us to overestimate the mass of the individual clusters, and hence of each CNSFR. However, we cannot be sure that we are actually measuring their velocity dispersion, and thus we prefer to say that our measurements of  $\sigma_*$ , and hence the dynamical masses, constitute upper limits.

We have found indications for the presence of two different kinematical components in the ionized gas of the regions. The narrow component of the two-component Gaussian fits seems to have a relatively constant value for all the studied CNSFRs, with estimated values close to  $25 \text{ km s}^{-1}$ . This narrow component could be identified with ionized gas in a rotating disc, while the stars and the fraction of the gas (responsible for the broad component) related to the star-forming regions would be mostly supported by dynamical pressure. To disentangle the origin of these two components it will be necessary to map these regions with higher spectral and spatial resolution and a much better signal-to-noise ratio, especially for the  $O^{2+}$  lines.

The observed stellar and  $[O III]$  rotational velocities of NGC 2903 are in good agreement, while the  $H\beta$  measurements show shifts similar to those found between the narrow and broad components. In the case of NGC 3310 the rotation curve shows a typical S feature, with the presence of some perturbations, in particular near the location of the Jumbo region. For NGC 3351, the rotation velocities derived for both stars and gas are in reasonable agreement, although in some cases the gas shows a velocity slightly different from that of the stars. For the three galaxies, the rotation curve corresponding to the position going through the centre of the galaxy shows maximum and minimum values at the position of the circumnuclear ring.

**Acknowledgments.** Financial support for this work has been provided by the Spanish Ministerio de Educación y Ciencia (AYA2007-67965-C03-03).

## References

- Hägele, G. F., Díaz, Á. I., Cardaci, M. V., Terlevich, E., & Terlevich, R. 2007, MNRAS, 378, 163
- 2009, MNRAS, 396, 2295
- 2010, MNRAS, 402, 1005